

Presentation Outline

- Building Background
- Existing Systems Summary
- Design Objectives
- Mechanical Depth CHF
 - CHP Screening Process
 Energy Analysis
 - Central Plant Redesign
 - Electrical System Integration
 - Cost Breakdown and Emission
 - Summary and Recommendation



- Electrical Breadth PV Panels
 System Sizing
- Cost Estimate and Payback
 Electrical System Integration
- Summary and Recommend
- onclusions

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Building Background

- General Building Information
 - Owner • Miller Children's Hospital
 - Project Size127,000 square feet
 - Total Cost
 - \$151,000,000 (estimated)
 - Design-bid-build
 - Completion Date
 - Fall 2009



Building Background

- The Pediatric Inpatient Addition
 - 4-Story Hospital Facility
 - 7 Operating Rooms
 - Neonatal Intensive Care Unit
 - Utilizes Green Roof System

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Existing Systems Summary

Mechanical System

7 Air Handling Units (located on roof)
Constant Volume with Space Reheat
HEPA Filters Used for Operating Rooms
(2) 500 ton Centrifugal Water Cooled Chillers

- (2) Induced Draft Cooling Towers
- (2) 2,000 MBh Gas-Fired Hot Water Boilers



Existing Systems Summary Condenser Water Flow Diagram 303/37 BIR DELIGI BULL BULL **Chilled Water Flow Diagram** 1812-10. NULTRAL milt 80 22... SURVEY DALS 85.5. DRIVER MAN CONCERNS. 2275. 10.10. Marris Status 2279. ALC: NO. COLUMN STATE -10 Hot Water Flow Diagram

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Existing Systems Summary

Electrical System

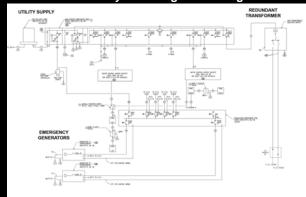
Electric Utility – Southern California Edison
 480Y/277V 3-phase 4-wire secondary

- (2) 750 kW emergency generators
- 10,000 kW redundant transformer
 Miller Children's Hospital
 Does not serve loads
 East future use and evere performer



Existing Systems Summary

Electrical System Single Line Diagram



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Design Objectives

Main Objectives

• Reduce energy consumption • Cut back on emissions



Design Objectives

Energy Consumption • Electricity - 5,900,000 kWh/year • Gas - 38,000 therms/year

Operational Costs

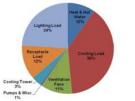
• Electricity - \$1,100,000/year • Gas - \$30,000/year

Emissions (Utility Generated)

• NO_x - 6,000 lbs/year

• CO2 - 3,800 lbs/year

Annual Energy Consumption



• SO_X - 5,000 lbs/year

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CHP Screening Process

Spark Spread

- -The difference between electricity and gas rates in \$/MMBtu
- Cost of electricity (> \$0.05/kWh)
- Cost of gas(< \$4.00/MMBtu)



Mechanical Depth Combined Heat & Power

Energy Costs and Consumption

	Energy Costs	Energy Consumption
Electricity	\$0.187/kWh	5,915 MWh
Natural Gas	\$8.01/MMBtu	3,811 MMBtu

General Factors Affecting CHP

Factors Favoring	Spark Spread	Elec. Cost	NG Cost	Elect. Load	Thermal Load
CHP Feasibility:	\$/MMBtu > 12	\$/kWh	\$/MMBtu	Avg/peak	Avg/peak
	>12	> 0.05	< 4.00	> 0.7	> 0.7
Value for Site:	46.78	0.187	8.01	0.74	0.25

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Mechanical Depth Combined Heat & Power

Energy Analysis

Peak Electric Load
 September 6 at 5:00 pm
 OO kW

- Peak Heating Load

 January 1 at 7:00 am (T_{oA} = 4)
 -1,700 MBh
- Peak Cooling Load

September 6 at 5:00 pm (1_{0A} = 91°F)
 225 tons



<figure>

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Mechanical Depth Combined Heat & Power

Energy Analysis

Peak Electric Load – 900 kW

- 1,035 kW generator required

Use reciprocating engine

Cannot use absorption cooling

- Generator size too small

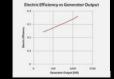
Generator Operation Condition
 Demand output

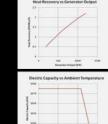


Mechanical Depth Combined Heat & Power

Caterpillar Reciprocating Engine

Caterpillar Engine								
Model No. G3606 T 130 LE								
	1,075	kW						
	10.64 MMB	:u/h (HHV)						
	2.03 MN	1Btu/h						
Electrical	Thermal	Ove	rall					
34.47%	19.03%	53.5	0%					
CO2	со	Nox	Sox					
110	0.506	4.08	0.000588					
	Electrical 34.47% CO2	Model No. G3606 T 130 1,075 10.64 MMBi 2.03 MM Electrical Thermal 34.47% 19.03% CO2 CO	Model No. G3606 T 130 LE 1,075 kW 10.64 MMBtu/h (HHV) 2.03 MMBtu/h Electrical Thermal Ove 34.47% 19.03% 53.5 CO2 CO Nox					





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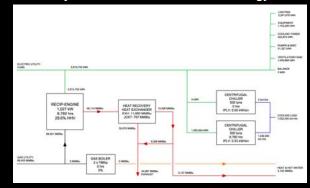
• Recovered Heat Energy

• System Schematic

Heat Recovery Heat Exchanger Operation							
	Jacket (MBtuh)	Exhaust (MBtu/h)	Total (MBtuh)				
Annual Operating Hours	8,760	8,760	8,760				
Minimum Heat Recovery	0.54	0.45	0.98				
Maximum Heat Recovery	0.84	0.92	1.77				
Mean (Average) Heat Recovery	0.71	0.71	1.42				



Mechanical Depth Combined Heat & Power CHP System Schematic and Annual Energy Use



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Mechanical Depth Combined Heat & Power

Central Plant Redesign

Located north of the Pediatric Inpatien

- Comprised of:
 - Pump Room
 - Chiller Room
 - Electrical Switchge
 - Emergency Generator Roor
 - -Transformer Yard
- New Generator Room 1,180 sq. ft.



Mechanical Depth Combined Heat & Power

Existing Central Plant



Central Plant Area = 4,700 sq. ft.

New Central Plant Area = 5,880 sq. ft. 25% Increase

CHP Plant Redesign

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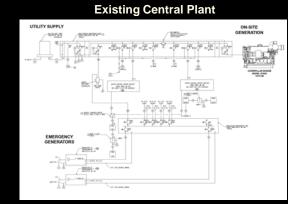
Electrical System Integration

Generator replaces redundant

- ansformer
- Key Switch
- Fire pump moved
- Emergency generators not required by
- code



Mechanical Depth Combined Heat & Power



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Mechanical Depth Combined Heat & Power

Cost Breakdown and Emissions

Estimated Cost: \$1,600,000

Annual Building Operational Cost

Savings: \$340,000/year

Less maintenance costs for the system

Estimated Payback: Less than 5 year

Cogen E	quipment	
Nominal Capacity = 1,075 kW		
Item	Equipment Costs per kW	Total \$
Generator Set Package	\$281	\$302,075
Heat Recovery	\$87	\$93,525
Interconnect/Electrical	\$38	\$40,850
Labor/Materials	\$364	\$391,300
CM and Engineering Fees	\$224	\$240,800
	SubTotal =	\$1,068,550
Central Pla	nt Expansion	
Area = 1,180 sf		
Item	Cost per sq. ft.	Total \$
Substructure	\$84.32	\$99,500
Shell	\$136.44	\$161,000
Interiors	\$23.31	\$27,500
Services	\$86.44	\$102,000
Contractor Overhead/Profit	\$82.63	\$97,500
Architectural Fees	\$28.81	\$34,000
1992 117 - SAC COLOR 64	SubTotal =	\$521,500

Mechanical Depth Combined Heat & Power

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		Paul	Peak	Delivery	Demand	Total	MonthlyLise	On peak	Mid-peak	Off-peak	Charges	Getüte	Charge	gas	Monthly Cost	
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	April	\$.78		. \$8.20	\$0.00	58,325.53	487,212		190,013	297,199	\$76,625.15	2,688	50.09	56.61	51,894.70	
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	June	294	+	39.20	\$15.62	\$22,431.40	5/12,294	125,827	90,411	236,256	581,464.33	2,451	\$6.09	\$5.73	\$2,017.83	
Lone	NY.	294	+	29.20	115.42	\$22,441.33	526,648	142,295	\$4,797	185,657	\$17,113,27	2,590	\$1.09	51.80	\$2,500.54	
_	August	900	+	39.20	\$15.62	\$22,547.77	112,625	343,809	11,672	292,964	\$88,906.11	2,574	\$0.09	\$6.57	\$1,689.43	
	September	908		29.30	\$15.42	\$22,793.78	111,946	134,325	82,150	381,970	\$#3,070.3#	2,489	50.08	\$5.58	\$2,684.86	
	October	.885		39.20	\$0.00	34,358.85	116,122		201,288	114,834	541,171.95	1,879	50.09	\$6.57	\$1,864.81	
Winter		862		09.20	\$0.00	54,182.03	472,395	8	184,312	266,263	\$36,326.37	8,381	\$0.09	\$6.71	\$2,581.62	
writer																Twarly Total
writer	December	#13	+	\$9.30	\$0.00	58,077.13	471,256		181,787	257,431	\$18,338.66	4,985	\$2.05	\$2.69	\$3.841.40	
writer		#13	1	193.20	\$0.00 701al -	5155.881.24	heready, full (the set		and the second	Total +	2948,676,30	Lage States	\$2.05	52.69 Total +	\$3.8#1.40 \$30,540.35	Twarty Total SL335,077.8
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willer		Parte Sc Paule	Adjusted Peak	Delivery	Total +	5135,861,24 Cog	en Scenario - 187	WW Recipes	Cating Engine Dectric Use Mid-piek	Total = operating at Off-peak	2948,476.30 sing demand ca	Schedule Get Use	T - Electric Gene Natural Gen Transmission Charge	Tetal + Cartiers Cont of gas	\$30,540.35	
willer		Parte Sc Paule VW	Adjusted	Delivery	Solal + Charge Demand	5135,861.24 Cop	en Scemario - 307	W Recipe	Cating Engline	Total + operating ai	2948,476.30 sing demand ca Monthly	Schedule	T - Electric Gene Natural Gen Transmission Charge Mitners	Tetal + cation Contien Cost of	530,540.39	
willer	December	Parte Sc Paule VW 847	Adjusted Peak WW	Delivery S/key 19.20	Total + mand Denand 5/km \$5.00	SUSS. BIO. 24 Cop Tutal 1 S249. 77	Northly Live	Ch-pask ktah	Dettric Use fold-peak KWh II	Total + operating al Off.peak Kith B	SHEATE 20 Monthly Charges 50.50	Schedule Set Une Haem 41,000	F - Electric Game Natural Gan Transmission Charge Mitness \$2.08	Total + ration Cost of gas S/there \$2.58	520,540.35	
	December (shorty Zebrury	Parte Sc Parale VW 842 343	Adjusted Peak KW 0 0	Delivery S/km 19.30 19.20	Total + Onarge Demand 5/4m \$5.00 \$5.00	5135.861.24 Cop Total 1 5249.77 5249.77	Monthly Live	Chi peak	Cleans to a construction of the construction o	Total = operating all Off geak KMN B B	Monthly Charges 5 30.00	Schedule Gatilte Hann 41,000 57,534	F - Electric Gene Natural Gen Transmission Charge Mitnem Sc.08 30.08	Total + ration Cost of gas S/Tharm \$2.38 \$2.43	520,540.35 MontNy Cuet 5 538,623.75 538,785.22	
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Presentation Outline

Building Background

- Existing Systems Summary
- Design Objectives
- Mechanical Depth CHP
- CHP Screening Process
- Energy Analysis
- Central Plant Redesign
- Electrical System Integration
- Cost Breakdown and Emissions
- Summary and Recommendation



Electrical Breadth – PV Panels
 System Sizing
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Conclusions

Mechanical Depth Combined Heat & Power

Cost Breakdown and Emissions

ecrease in SO_X and CO₂ emissions crease in NO_X emissions - Generator less efficient at part-load - Higher emissions per unit of energy generated - Utilify generator operates at higher efficiency - California guidelines in place for utility emissions atalytic Reduction Systems - Treats exhaust gas after it leaves the engine - Uses toxic reagents such as ammonia - Betential health picks with vacation and on site



Mechanical Depth Combined Heat & Power

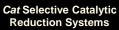
Emissions Data Pounds of Emissions per Year

 On-Site Generation
 Utility Generation

 NO_x
 12,234
 5,951

 SO_x
 232
 5,029

 CO₂
 3,761
 3,782





Reduces CO by 93%
Reduces NO_X by up to 90%

Cat Oxidation Catalysts



Reduces CO by 93%
 Reduces hydrocarbons by more than 40%

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Mechanical Depth Combined Heat & Power

Summary and Recommendation

- Total System Cost: \$1,850,000
 Includes Catalytic Reduction System
- Total Annual Savings: \$320,000/year
 Includes maintenance costs for CRS
 20% reduction is experiment each
- Payback Period: Less than 6 years
- Reduced Emissions with CRS
- Recommendation: Install CHP System



Mechanical Depth Combined Heat & Power

System Cost

CHP Equipment Costs: \$1,100,000 Central Plant Expansion: \$500,000 Catalytic Reduction System: \$250,000 Total CHP System Cost: \$1,850,000

Maintenance Costs

CHP Maintenance Costs: \$65,000/year CRS Maintenance: \$25,000/year Total Maintenance Cost: \$90,000/year

Annual Savings

CHP Operation Savings: \$410,000/year Maintenance Costs: \$90,000/year Total Annual Savings: \$320,000/year

Important Notes

Efficient CHP systems utilize ALL recovered heat
Size of building electric demand plays a big role (> 2 Megawatts)
Utility rates very important factor

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• Electrical Breadth – PV Panels

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Electrical Breadth Photovoltaic Panels

System Sizing

- Photovoltaic array located on roof
 Pediatric Inpatient Addition upper roof
 Pediatric Inpatient Addition lower roof
 Miller Children's Hospital roof
- Total panel coverage: 12,310 sq. ft.
- *BP Solar* panel selected - Model BP 175B
 - Rated power: 175W
 - 14% Nominal Efficien
- 900 PV panels used



Electrical Breadth Photovoltaic Panels

Areas

- Pediatric Inpatient Addition
 Upper roof: 7,700 sq. ft.
 Lower roof: 3,240 sq. ft.
- Miller Children's Hospital: 11,060 sq. ft.
- Assumed Coverage
 PIA: 80%
- MCH: 60% (rooftop equipment)
- Assumed 80% Usable PV Area
- Total Panel Coverage: 12,310 sq. ft.
- Individual Panel Area: 13.56 sq. ft.
- 900 Panels Calculated

PV Panel Coverage



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Electrical Breadth – PV Panels System Sizing Cost Estimate and Payback

Electrical System Integration
 Summary and Recommendation

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Electrical Breadth Photovoltaic Panels

Cost Estimate and Payback

 Renewable energy delivered: 245,000 kWh/year

- Maximum capacity: 140 kW AC
- Electricity savings: \$46,000/year
- System cost: \$1,482,250
- Incentives package: \$1,192,200
- Payback Period: 7 years



Electrical Breadth Photovoltaic Panels

System Cost

Development & Engineering Fees: \$70,000
 PV Modules: \$945,000
 Module Support Structure: \$123,100
 Inverter: \$100,800
 System Installation: \$236,000
 Total Cost: \$1,482,250

Incentives Package

 California State Rebate (Performance Based Incentive): \$478,980
 Federal Investment (10%) Tax Credit: \$197,582
 State Solar Energy (7.5%) Tax Credit: \$148,187
 Federal Accelerated Depreciation (34% tax rate):
 \$328,770
 State Depreciation Savings (8% tax rate): \$38,679
 Total Package: \$1,192,200

Net PV System Cost by Year

Year	Total System Cost	SCE PBI Program	10% Federal Tax Credit	7.5% State Tax Credit	Federal Depreciation Savings	State Depreciation Savings	Estimated Energy Savings	Net System Cost
1	(\$1,482,250)	\$478,980	\$196,123	\$147,092	\$197,262	\$7,736	\$45,933	(\$409,124)
2	and the second second				\$52,603	\$12,377	\$45,478	(\$298,665)
3					\$31,562	\$7,426	\$45,028	(\$214,649)
4					\$18,937	\$4,456	\$44,582	(\$146,674)
5					\$18,937	\$4,456	\$44,141	(\$79,140)
6					\$9,469	\$2,228	\$43,704	(\$23,740)
7			Break ever	in 7 years			\$43,271	\$19,531
8							\$42,843	\$62,374
9							\$42,419	\$104,793
10							\$41,999	\$146,792

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Electrical Breadth – PV Panels System Sizing

Cost Estimate and Payback
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Electrical Breadth Photovoltaic Panels

Electrical System Integration

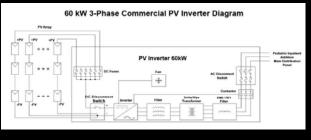
/ Inverter

- Converts DC current into AC current -*Solectria* PVI Gridtie Inverters - Miller Children's Hospital: 60 kW - Pediatric Inpatient Addition: 82 kW



Electrical Breadth Photovoltaic Panels

Commercial PV Inverter Diagram



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• Electrical Breadth – PV Panels

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Electrical Breadth Photovoltaic Panels

Electrical System Integration

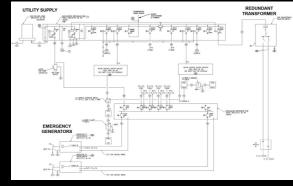
ectrical System

- Spare breaker on main distribution panel (#4)
 New breaker size: 200A
 Inverters connected through single feeder
 Feeder size: (4) 3/0 + (1) #6 ground
 Conduit size: 2"
 Distance to main distribution panel: 240 ft
 V/blace drop 1 55% < 2%
- System sized using NEC 2005



Electrical Breadth Photovoltaic Panels

PV Electrical System Single Line Diagram



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Electrical Breadth – PV Panels System Sizing Cost Estimate and Payback

- Electrical System Integration
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Electrical Breadth Photovoltaic Panels

Summary and Recommendation

- \$46,000 annual savings
- Payback period of 7 years
- Not possible without incentives package
 Costs more than to purchase from utility
- Risky decision
 - Available money fluctuates
 - Could be cut off if funds run out



Electrical Breadth Photovoltaic Panels

Summary and Recommendation

- Non-renewable energy savings
- Greenhouse gas reductions
- Recommendation: Install PV System

Presentation Outline

Building Background

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 Electrical Breadth – PV Pane System Sizing Cost Estimate and Payback Electrical System Integration Summary and Recommendation Conclusions

Conclusions

Design Goals

- Reduce energy consumption
- Save money on operational costs
- Cut back on emissions

Can be achieved with energy efficient mechanical systems and renewable energy sources



Miller Children's Hospital Pediatric Inpatient Addition Long Beach, CA

The Pennsylvania State University Architectural Engineering



Special Thanks to:

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Also, a special thanks to my parents for all their support over the years

Questions?